Thermal photons from $\pi\rho \rightarrow \pi\gamma$ revisited

Jan-e Alam[1], Pradip Roy[2] and Sourav Sarkar[1]
[1] *Variable Energy Cyclotron Centre, Kolkata 700064, India*
[2] *Saha Institute of Nuclear Physics, Kolkata 700064, India*
(Dated: February 1, 2008)

We evaluate the photon spectra from the reaction $\pi\rho \rightarrow \pi\gamma$ for the exchange of π, ρ, ω, ϕ and a_1 as intermediary mesons. It is found that the contributions from the intermediary a_1 is more than any other meson exchange processes up to photon energies 2.5 GeV.

PACS numbers: 25.75.-q,12.40.Vv,13.85.Qk,21.65.+f

Investigation of the properties of hot and dense hadronic matter produced in high energy heavy ion collisions through real and virtual photon spectra is a field of great contemporary interest. As the energy density of the hadronic matter increases, the system is expected to go to a new phase of matter called quark gluon plasma (QGP). Among others, photons are considered as a very promising signal of QGP [1]. However, to estimate the photons from QGP an accurate evaluation of the photon spectra from hadrons is necessary [2]. Among all the processes which produces photons in a hot hadronic system the reaction $\pi\rho \rightarrow \pi\gamma$ is the dominant one for photon energies (E) above 0.5 GeV.

In a recent paper [3] it was claimed that the t channel ω exchange in $\pi\rho \rightarrow \pi\gamma$ is the single most dominant process of photon production for $E > 2$ GeV. For $\pi - \rho - a_1$ vertices they have employed the Massive Yang-Mills approach and the $\pi - \rho - \omega$ interaction is similar to that given in [4]. It is the purpose of this paper to comment on the above observation.

We have made a detailed study of this process considering all possible diagrams involving π, ρ, ω, ϕ and a_1 mesons in the intermediate state. For this purpose the following interactions have been considered. For the $\pi - a_1 - \gamma$ and $\pi - a_1 - \rho$ vertices we employed the phenomenological interactions from Ref. [5], (see also [6]) which reproduces the $a_1 \rightarrow \pi\,\rho$ and $a_1 \rightarrow \pi\,\gamma$ decay widths reasonably well. It may be mentioned here that the $a_1\pi\gamma$ vertex used in Refs.[7, 8] gives a larger value of the above decay width compared to the experimental value. The $\omega - \rho - \pi$ interaction is taken from [4]. The coupling constants has been fixed (via vector meson dominance) to reproduce the $\omega \rightarrow \pi^0\,\gamma$ decay width. For the sake of completeness we have also considered ϕ mediated reactions, though its contribution is found to be small. The interaction vertex for $\phi - \rho - \pi$ is similar to $\omega - \rho - \pi$ and the coupling is constrained from the decay $\phi \rightarrow \pi^0\,\gamma$. The $\rho - \pi - \pi$ vertex has been fixed from $\rho \rightarrow \pi\pi$ decay. All the reactions involving intermediary π, ρ, a_1, ω and ϕ as well as four point $\pi - \rho - \pi - \gamma$ interactions have been considered. We have not introduced form factors at the vertices because the main focus of the work is to compare the relative importance of the ω and a_1 exchange reactions. Coherent sums have been performed for the same class of relevant diagrams for all the intermediary mesons.

The emission rate of photons from $\pi\rho \rightarrow \pi\gamma$ is plotted in Fig. 1 at a temperature $T = 200$ MeV. Our results do not agree with that of Ref. [3] *i.e.* ω-exchange in the $t-$ channel is not the single most important process for the entire range of E considered here. In fact up to $E \sim 2.5$ GeV the emission rate due to a_1-exchange processes is seen to be the most dominant one. We have also observed that the a_1 exchange in the s channel is more dominant than the corresponding t channel exchange as claimed in [8]. The contribution from ω exchange processes in the s and t channels is found to be comparable to the a_1 exchange processes beyond $E \sim 2.5$ GeV. The decay of ω meson is not considered here to avoid double counting with the s channel ω exchange process. Contribution from ϕ exchange is negligibly small.

In summary, we have evaluated the production rate of photons by the reactions $\pi\rho \rightarrow \pi\gamma$ with all the possible charge states of π and ρ. An exhaustive set of processes involving intermediary π, ρ, ω, ϕ and a_1 mesons have been considered. We observe that the contributions from the a_1 exchange process is the dominant one for photon energies up to 2.5 GeV. It should be mentioned here that beyond $E = 2.5$ GeV photons from hard QCD processes may mask the thermal contributions.

[1] J. Alam, S. Sarkar, P. Roy, T. Hatsuda and B. Sinha, Ann. Phys. (NY), **286**, 159 (2000); J. Alam, B. Sinha and S. Raha, Phys. Rep. **273**, 243 (1996).

[2] J. I. Kapusta, P. Lichard, and D. Seibert, Phys. Rev. D **44**, 2774 (1991); S. Sarkar, J. Alam, P. Roy, A. K. Dutt-Mazumder, B. Dutta-Roy and B. Sinha, Nucl.

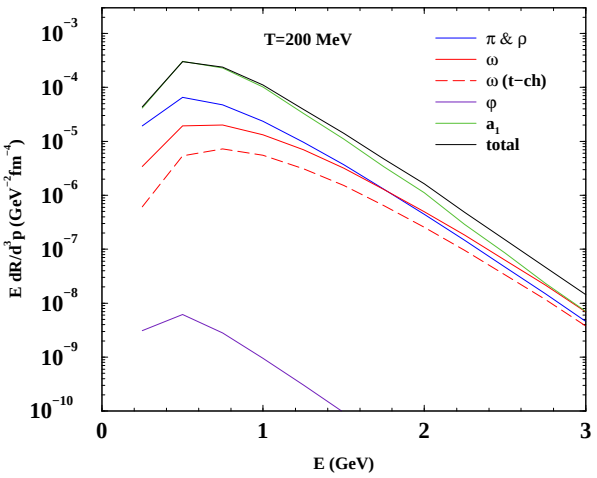

FIG. 1: Thermal photon emission rates from the reaction $\pi\rho \rightarrow \pi\gamma$ at T=200 MeV. Red dashed (solid) line indicates contribution from ω exchange in t (s +t) channel. Blue (green) line shows the spectra for π and ρ (a_1) exchange processes. Contributions from ϕ exchange processes is shown by violet line. The total contribution is indicated by the solid (black) line.

Phys. A **634**, 206 (1998); P. Roy, S. Sarkar, J. Alam and B. Sinha, Nucl. Phys. A **653**, 277 (1999).
[3] S. Turbide, R. Rapp and C. Gale, hep-ph/0308085.
[4] M. Gell-Mann, D. Sharp and W. D. Wagner, Phys. Rev. Lett. **8**, 261 (1962).
[5] P. Ko and S. Rudaz, Phys. Rev. D **50**, 6877(1996); J. K. Kim, P. Ko, K. Y. Lee and S. Rudaz, Phys. Rev. D **53**, 4787(1996).
[6] Y. C. Shin, M. K. Cheoun, K. S. Kim and T. K. Choi, Eur. Phys. J. A **14**, 87 (2002).
[7] C. Song, Phys. Rev. C **47**, 2861 (1993).
[8] L. Xiong, E. V. Shuryak, and G.E. Brown, Phys. Rev. D **46**, 3798 (1992).